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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

DITCHING INVESTIGATION OF A $\frac{1}{10}$ -SCALE MODEL

OF THE GRUMMAN F9F-2 AIRPLANE

TED NO. NACA DE 335

By Lloyd J. Fisher and Ellis E. McBride

Langley Aeronautical Laboratory
Langley Air Force Base, Va.

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SUMMARY

An investigation was made of a $\frac{1}{10}$ -scale dynamically similar model of the Grumman F9F-2 airplane to study its behavior when ditched. The model was landed in calm water at the Langley tank no. 2 monorail. Various landing attitudes, speeds, and configurations were investigated.

The behavior of the model was determined from visual observations, acceleration records, and motion-picture records of the ditchings. Data are presented in tabular form, sequence photographs, time-history acceleration curves, and plots of attitude and speed against distance after contact.

From the results of the investigation it was concluded that the airplane should be ditched at the 12° landing attitude (slightly below the stall angle) with the outboard landing flaps down 55° and the inboard landing flaps down 20° . The landing gear should be retracted. The wing tanks should be retained for additional buoyancy if they are empty. If the tanks contain fuel, the fuel should be jettisoned or the tanks should be dropped to decrease the gross weight and to obtain a lower landing speed. In a calm-water ditching under these conditions the airplane will probably skip and porpoise in a run of about 700 feet. If a ditching with the landing gear extended is unavoidable, the airplane should contact the water at the highest attitude obtainable and lowest possible forward speed. The fuselage speed brake open 30° would improve the ditching behavior if it were made about three times the present strength.

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INTRODUCTION

An investigation of a dynamic model of the Grumman F9F-2 airplane was conducted in calm water at the Langley tank no. 2 monorail to determine the probable ditching performance of the airplane and to determine the best way to land it on water. The investigation was requested by the Bureau of Aeronautics, Department of the Navy. The possibility of using the speed brake as a ditching aid was of interest should the behavior of the airplane be severe enough to warrant a ditching aid. Tests with the landing gear down were included in the investigation since a full-scale ditching had been made with this configuration and the pilot had been unhurt. Design information on the airplane was furnished by Grumman Aircraft Engineering Corporation.

APPARATUS AND PROCEDURE

Description of Model

A three-view drawing of the F9F-2 airplane is given in figure 1. A $\frac{1}{10}$ -scale dynamic model of the F9F-2 airplane, shown in figure 2, was furnished by the Bureau of Aeronautics. It was constructed of balsa wood and spruce and was ballasted internally to obtain scale weight and moments of inertia. The model had a wing span of 3.53 feet and an overall length of 3.77 feet.

The flaps were hinged and held in the down position by a strand of thread of the required strength. When a load of 70 pounds per square foot (full scale) was applied to the flaps the thread would break and the flaps would rotate to the neutral position. This method of fastening parts of the model at scale strength by thread was found to be accurate within ± 10 percent of the desired value.

The landing gear was keyed in position and fastened with thread of the required strength as shown in figure 3. When a load of 10,700 pounds (full scale) was applied in an aft direction at the axle of the nose gear, the thread would break and allow the gear to tear off. The main gear was arranged in a similar manner and would fail under a load of 24,800 pounds (full scale). A photograph of the model with the landing gear attached is shown in figure 4.

The speed brake was hinged so that it would open 30° and was held open by strands of thread of the required strength. The full-scale installation was designed to withstand a total load of about 6,600 pounds. A photograph of the model with the speed brake open 30° is shown in figure 5.

The hydrodynamic effect of probable bottom damage was investigated by installing the crumpled bottom shown in figure 6. The crumpled bottom was constructed of balsa wood and dented to conform with damage estimates based on the strength of the various fuselage panels replaced by the bottom. From the behavior of the undamaged model it was estimated that the rear portion of the fuselage would absorb the initial impact and suffer the greatest damage. On the basis of this, the crumpled bottom was installed aft of station 300.

Figure 7 shows the installation of the wing-tip fuel tanks. The tanks were tested at the empty weight since previous tests indicated that the additional weight of fuel is detrimental to ditching behavior.

Test Methods and Equipment

The model was launched by catapulting it from the Langley tank no. 2 monorail. The model left the launching carriage at scale speed and at the desired landing attitude, and the control surfaces were set so that the attitude did not change appreciably in flight. The behavior of the model was recorded from visual observations and by a high-speed motion-picture camera. The longitudinal and vertical accelerations were measured by a single-component time-history accelerometer placed in the pilot's cockpit. To obtain the two components of acceleration, the accelerometer was rotated and the tests repeated. The accelerometer had a natural frequency of about 20 cycles per second. It was damped to about 65 percent of critical dampening. The reading accuracy of the instrument was about $\pm \frac{1}{2}g$.

Test Conditions

(All values given refer to the full-scale airplane.)

Gross weight.- Most of the tests were made with the model weight corresponding to the full-scale gross weight of 12,100 pounds. The tests with the landing gear extended were made at a gross weight of 9,800 pounds.

Moments of inertia.- The moments of inertia used in the investigation are as follows:

I_x (roll), slug-feet ²	5,715
I_y (pitch), slug-feet ²	18,525
I_z (yaw), slug-feet ²	22,860

Location of the center of gravity.- The center of gravity was located at 27 percent mean aerodynamic chord and 3.0 inches below the fuselage reference line.

Landing attitude.- The model was ditched at attitudes of 4° , 8° , 12° , and 14° . The 4° attitude is close to the three-wheel landing attitude. The 8° attitude is an intermediate landing attitude. The 12° attitude is near the stall angle. The 14° attitude is slightly above the stalling angle and was used only in the tests with the landing gear extended. The attitude angle was measured between the fuselage reference line and the water surface.

Flap deflection.- Tests were made with the flaps in the standard landing configuration of outboard flaps extended 55° and inboard flaps extended 20° . The flaps were fastened down at scale strength.

Landing speed.- The landing speeds were such that the model was airborne within ± 4 knots of the landing speeds calculated from the lift curves supplied by the Grumman Aircraft Engineering Corporation.

Landing gear.- The majority of the tests were made with the landing gear retracted. However, some tests were made with the landing gear extended and fastened at scale strength. Unless otherwise specified, the tests were made with the landing gear retracted.

Conditions of simulated damage.- The model was tested in the following configurations:

- (a) No damage simulated.
- (b) Simulated crumpled bottom installed.
- (c) Simulated crumpled bottom installed and the nose-wheel door removed.
- (d) Simulated crumpled bottom installed and the speed brake open 30° .
- (e) Simulated crumpled bottom installed with the empty wing-tip tanks attached.
- (f) No damage with the landing gear extended and fastened at scale strength.

RESULTS AND DISCUSSION

A summary of the results of the investigation is presented in table I. The symbols used in the table are defined as follows:

- d violent dive - wings were submerged and angle between water surface and fuselage reference line was greater than 15°
- f flipped over - a rotation of 180° about transverse axis resulting in model coming to rest upside down
- n trimmed down - a negative rotation of less than 20° about transverse axis
- p porpoised - an undulating motion about transverse axis in which some part of the model was always in contact with water
- s skipped - an undulating motion about transverse axis in which model cleared water completely
- u trimmed up - a positive rotation of less than 50° about transverse axis

Effect of Attitude and Damage

In general, the motions made by the model were very much the same regardless of landing attitude or damage simulated. The model always trimmed down to a slightly negative attitude immediately after contact and then trimmed up violently and skipped clear of the water. Upon recontacting the water surface the model trimmed down, then trimmed up, and usually skipped again. The second skip generally was of shorter length than the first. Following the skips the model porpoised violently for the rest of the run out.

Plots of attitude and speed against distance after contact for the undamaged model are shown in figure 8 and for the model with simulated crumpled bottom installed in figure 9. From these plots the motions of the model and approximate speed at which these motions occurred can be seen. The dashed part of the attitude curve shows the length of the skip. When landed in the undamaged configuration less skipping and lower maximum accelerations occurred in the 12° attitude landings than in the 8° and 4° attitude landings (fig. 8, table I). When landed with the simulated crumpled bottom installed, the trimming up and skipping were least violent and the maximum accelerations (horizontal and vertical) were lowest in the 12° attitude landings (fig. 9, table I). Sequence photographs of model ditchings with the simulated crumpled bottom installed are shown in figure 10.

The violent motions made by the model and the slightly negative attitude attained after contact were considered dangerous and suggested the possibility of structural damage to the forward part of the fuselage. The model was therefore landed at the 12° attitude with the nose-wheel door removed to simulate its failure. The only appreciable effect was to shorten the total length of run. A plot of attitude and speed against distance after contact for this condition is shown in figure 9(d).

Since the least violent motions and lowest maximum accelerations observed were obtained in the 12° attitude landings, and because of the probability of less structural damage due to the lower landing speed, this attitude should be used for ditching.

Effect of Open Speed Brake

When the model was landed with the speed brake open 30° and fastened at scale strength the brake failed immediately after contact and had no effect on the motions of the model. The strength of the brake installation was increased to about three times scale strength before it would withstand the ditching loads and remain in the open position. Plots of attitude and speed against distance after contact with the speed brake open are shown in figures 9(e) and 9(f). These plots show that the open brake considerably reduced the maximum trim angle and kept the model from attaining a negative attitude at any time during the landing run. Although porpoising apparently increased near the end of the run, the dangerous motions during the high-speed portion of the run were considerably reduced.

These results indicate that it is of no consequence whether the airplane is ditched with the speed brake open or closed at its present strength. However, if the speed brake could be strengthened sufficiently to withstand the ditching loads, it would be beneficial as a ditching aid.

Effect of Wing-Tip Tanks

When the model was tested with the wing-tip fuel tanks attached, the tanks did not enter the water in the high-speed portion of the run so had little effect on the ditching motions. The wing tanks should, therefore, be retained for additional buoyancy if they are empty. If, however, the tanks contain fuel, the fuel should be jettisoned or the tanks should be dropped to decrease the gross weight and so obtain a lower landing speed.

Effect of Landing Flaps

The flaps, when fastened at scale strength, always failed immediately after contact with the water surface and caused no apparent detrimental behavior. However, when the flaps were fastened strong enough to withstand the water loads without failing, the model dived. Since the landing flaps are expected to fail, their use in the standard landing configuration of outboard flaps extended 55° and inboard flaps extended 20° is recommended in a ditching in order to obtain a low landing speed.

Effect of Extended Landing Gear

When the model was tested at the 12° landing attitude with the landing gear extended and fastened at scale strength, the main wheels contacted the water first and the model trimmed down rapidly. The forward part of the fuselage submerged and the model flipped over on its back. There was no failure of any part of the landing gear. The removal of the nose gear had no effect on the behavior of the model, that is, it continued to flip over on its back. When the model landed at a 14° landing attitude (slightly above the angle of maximum lift) it trimmed down and dived but did not flip over on its back. (At the 14° attitude the sinking speed corresponded to a full-scale sinking speed of about 275 feet per minute which was about 3.5 times as high as the sinking speed at the 12° attitude.) This behavior of the model at the 14° attitude was like the behavior of the full-scale airplane when ditched with the landing gear down since it did not flip over. However, in the full-scale ditching the nose gear failed and no failure occurred in the model tests.

Sequence photographs of the model ditching with wheels down at the 14° attitude are shown in figure 11. The longitudinal and vertical accelerations obtained in this configuration can be seen in figure 12. It appears that the extended main landing gear causes a nose-down moment the severity of which is decreased by increasing the sinking speed and decreasing the forward speed.

CONCLUSIONS

From the results of the investigation of a $\frac{1}{10}$ -scale model of the Grumman F9F-2 airplane the following conclusions were drawn:

1. The airplane should be ditched at the 12° landing attitude (slightly below the stall angle) with the outboard landing flaps down 55° and the inboard flaps down 20° . The landing gear should be retracted.

The wing tanks should be retained for additional buoyancy if they are empty. If the tanks contain fuel, the fuel should be jettisoned or the tanks should be dropped to decrease the gross weight and so obtain a lower landing speed.

2. In a calm-water ditching under these conditions the airplane will probably skip and porpoise in a run of about 700 feet.

3. If a ditching with the landing gear extended is unavoidable, the airplane should contact the water at the highest attitude obtainable and lowest possible forward speed.

4. The fuselage speed brake open 30° would improve the ditching behavior if it were made about three times stronger than the present strength.

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TABLE I

SUMMARY OF RESULTS OF DITCHING INVESTIGATION IN CALM WATER OF A

 $\frac{1}{10}$ - SCALE MODEL OF THE GRUMMAN F9F-2 AIRPLANE

[All values full scale; landing flaps inboard down 20°; outboard down 55°; gross weight 12,100 lb unless otherwise specified]

Landing attitude (deg)	Landing speed (knots)	Length of run (ft)	¹ Motions	Longitudinal deceleration (g)	Vertical acceleration (g)
No damage					
12	101.8	590	n, u, s ₈₀ , p	2	---
8	114.2	760	n, u, s ₅₀ , s ₉₀ , p	3	---
4	133	740	n, u, s ₁₅₅ , s ₈₅ , p	5	---
Simulated crumpled bottom installed					
12	101.8	700	n, u, s ₆₅ , s ₅₀ , p	2	6
8	114.2	685	n, u, s ₉₅ , s ₃₀ , p	3	6
4	133	760	n, u, s ₁₉₀ , s ₅₅ , p	5	7
Simulated crumpled bottom installed and nose-wheel door removed					
12	101.8	540	n, u, s ₄₅ , p	3	---
Simulated crumpled bottom installed and dive brake open 30°					
12	101.8	595	p, s ₅₀ , p	2	---
8	114.2	765	n, s ₇₀ , p	2	---
Simulated crumpled bottom installed with empty wing-tip tanks installed					
12	101.8	745	n, u, s ₁₀₀ , s ₆₅ , p	2	---
8	114.2	780	n, u, s ₁₂₀ , s ₆₅ , p	3	---
4	133	795	n, u, s ₇₅ , s ₇₀ , s ₅₀ , p	5	---
No damage with landing gear down fastened at scale strength; gross weight 9,800 lb					
14	82	92	d	6	4
12	91.7	106	f	8	6

¹Motions of the model are denoted by the following symbols:

- d violent dive
- f flipped over
- n trimmed down
- p porpoised
- s skipped (subscript denotes length of skip in feet)
- u trimmed up

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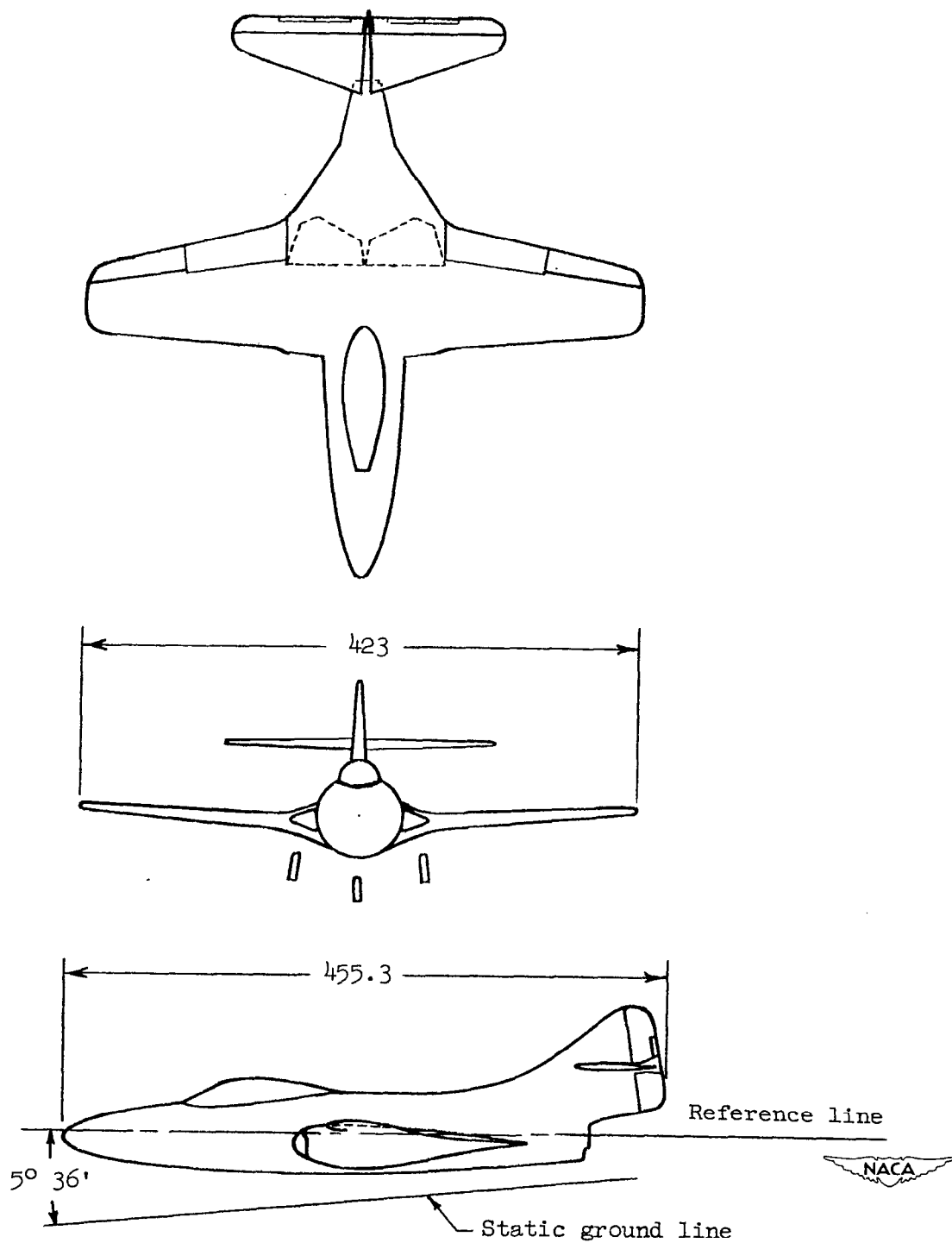
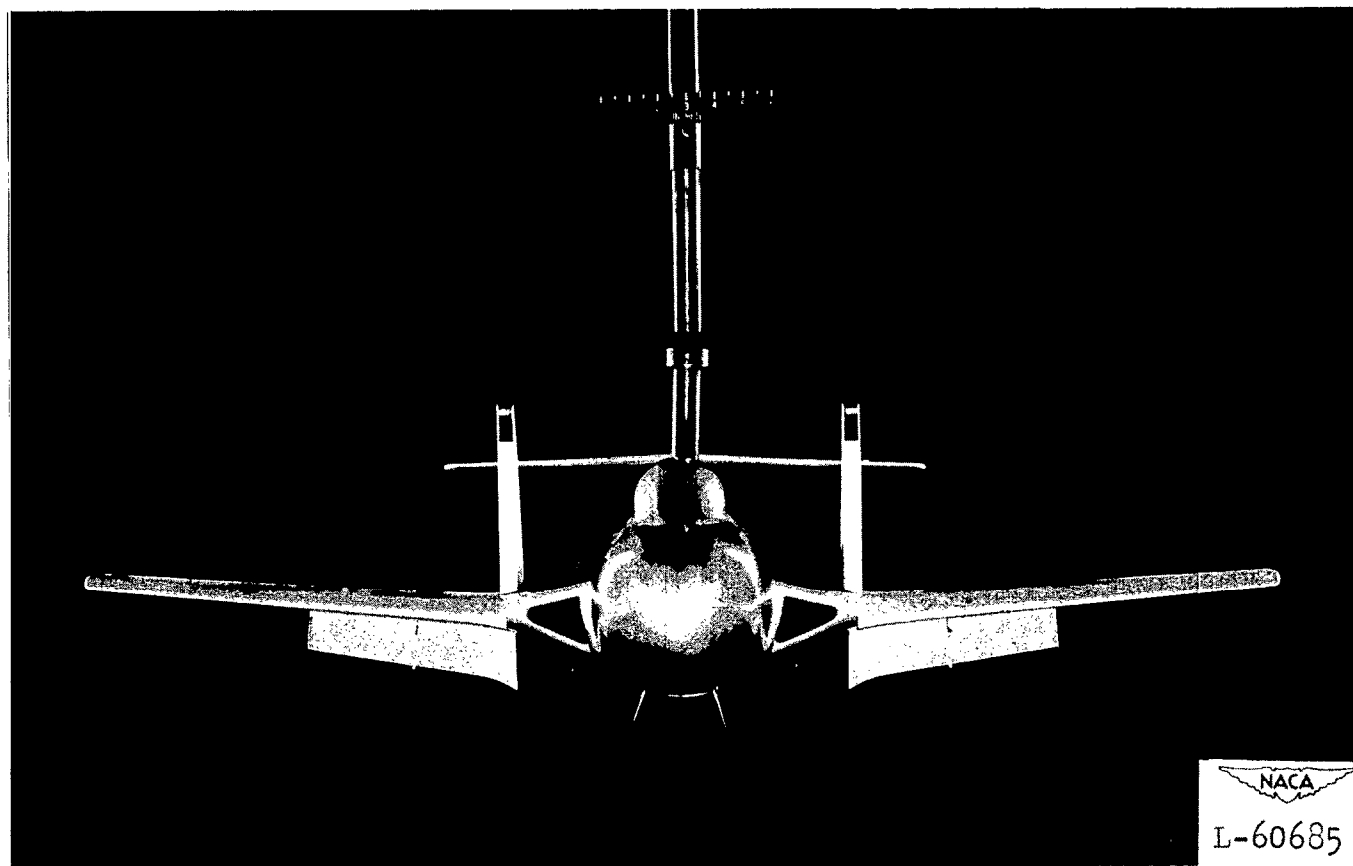


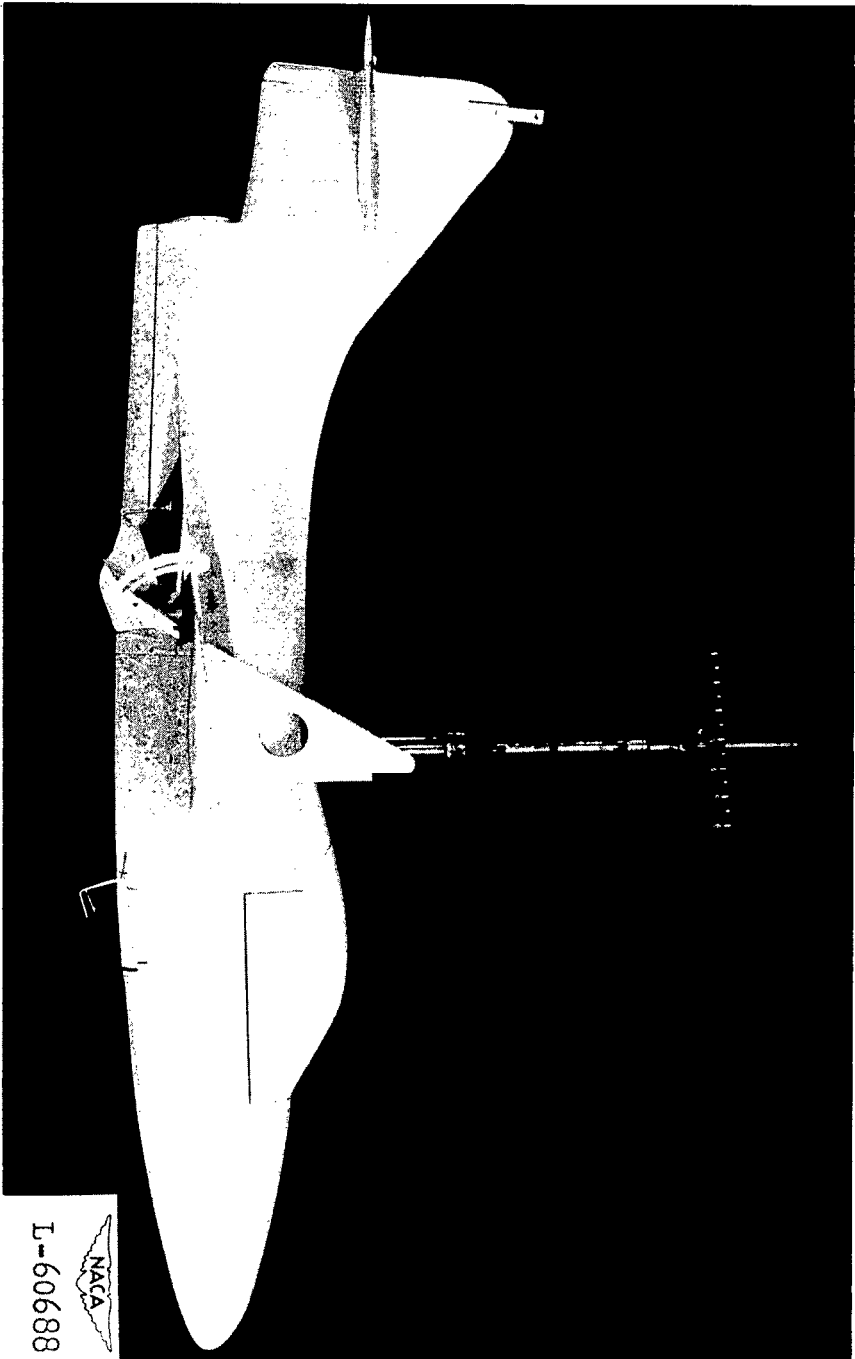
Figure 1.- Three-view drawing of the Grumman F9F-2 airplane.
(Dimensions are in inches, full size.)

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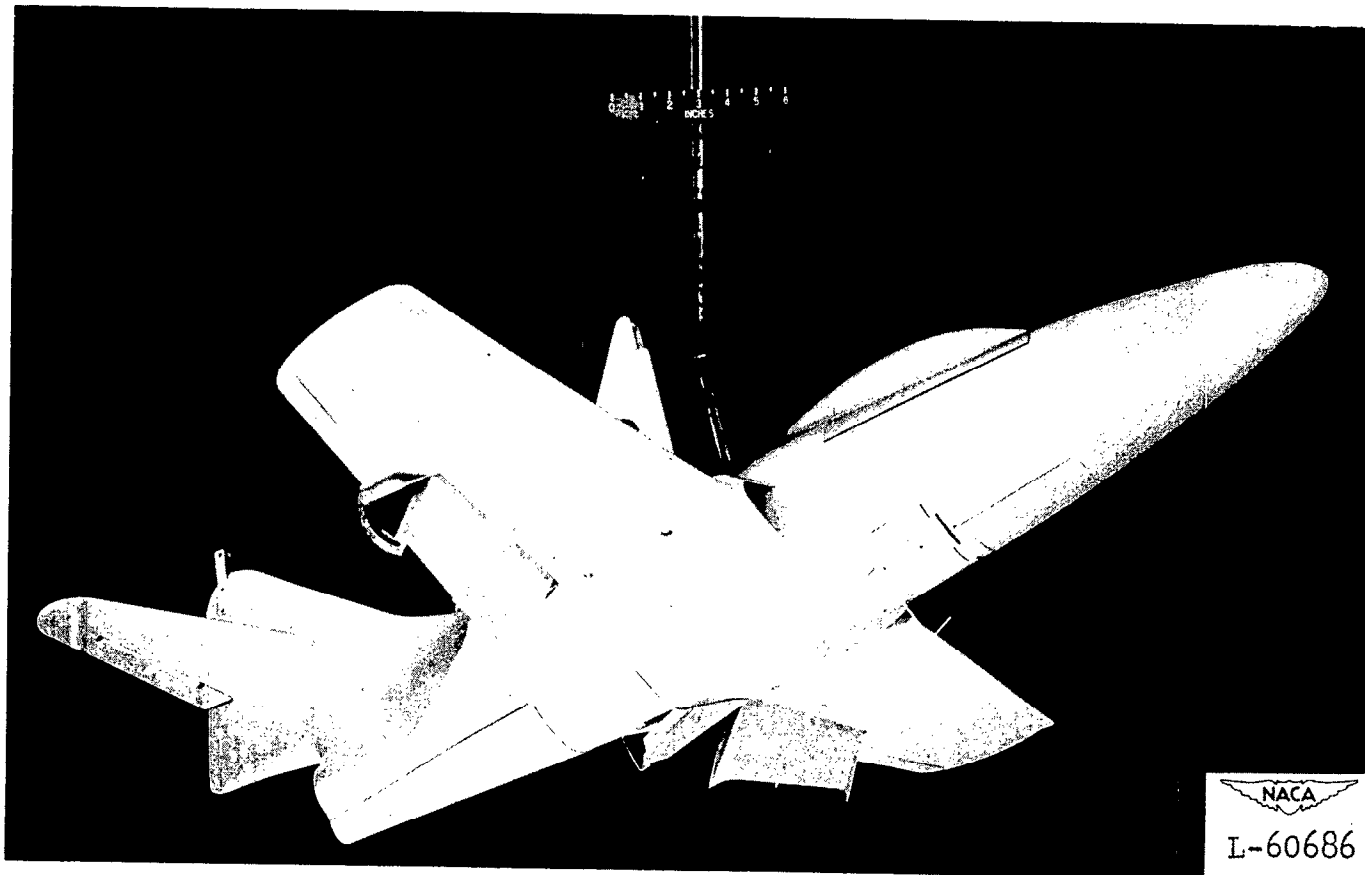
(a) Front view.

Figure 2.- The $\frac{1}{10}$ - scale model of the Grumman F9F-2 airplane.



(b) Side view.

Figure 2.- Continued.



(c) Three-quarter bottom view.

Figure 2.- Concluded.

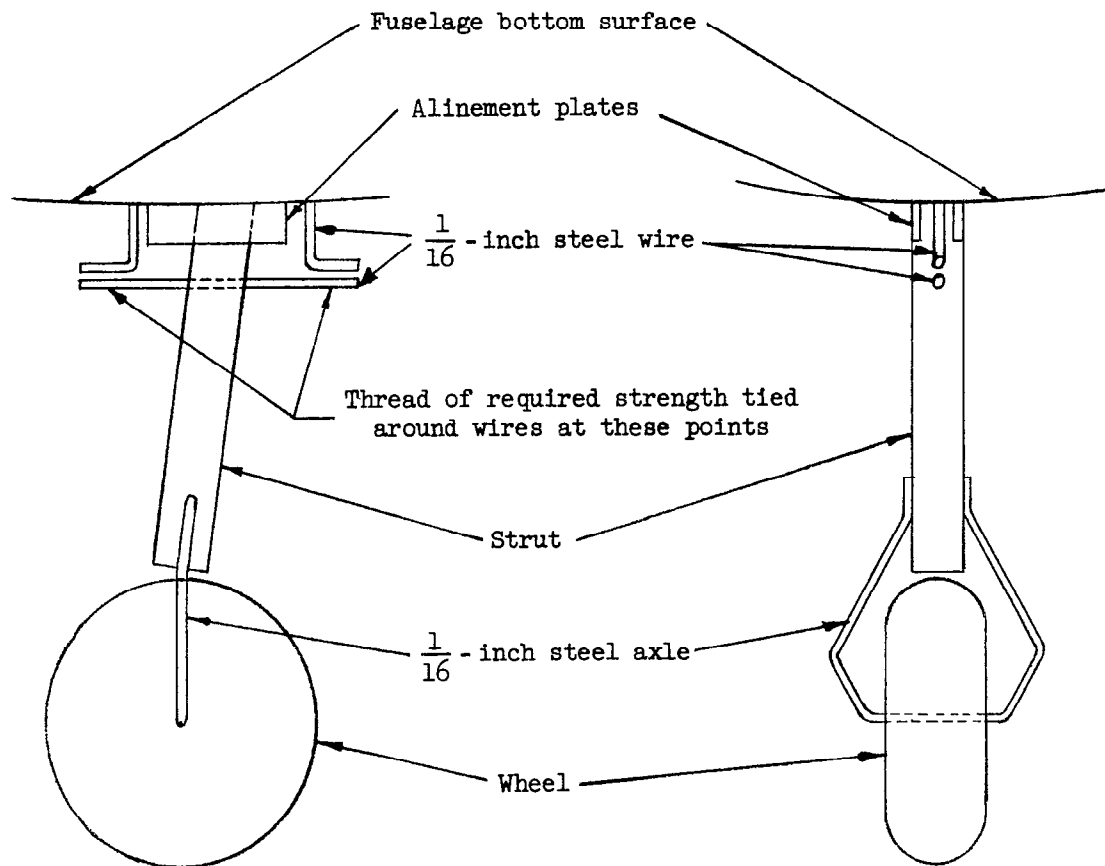


Figure 3.- Scale-strength installation of nose-wheel gear.

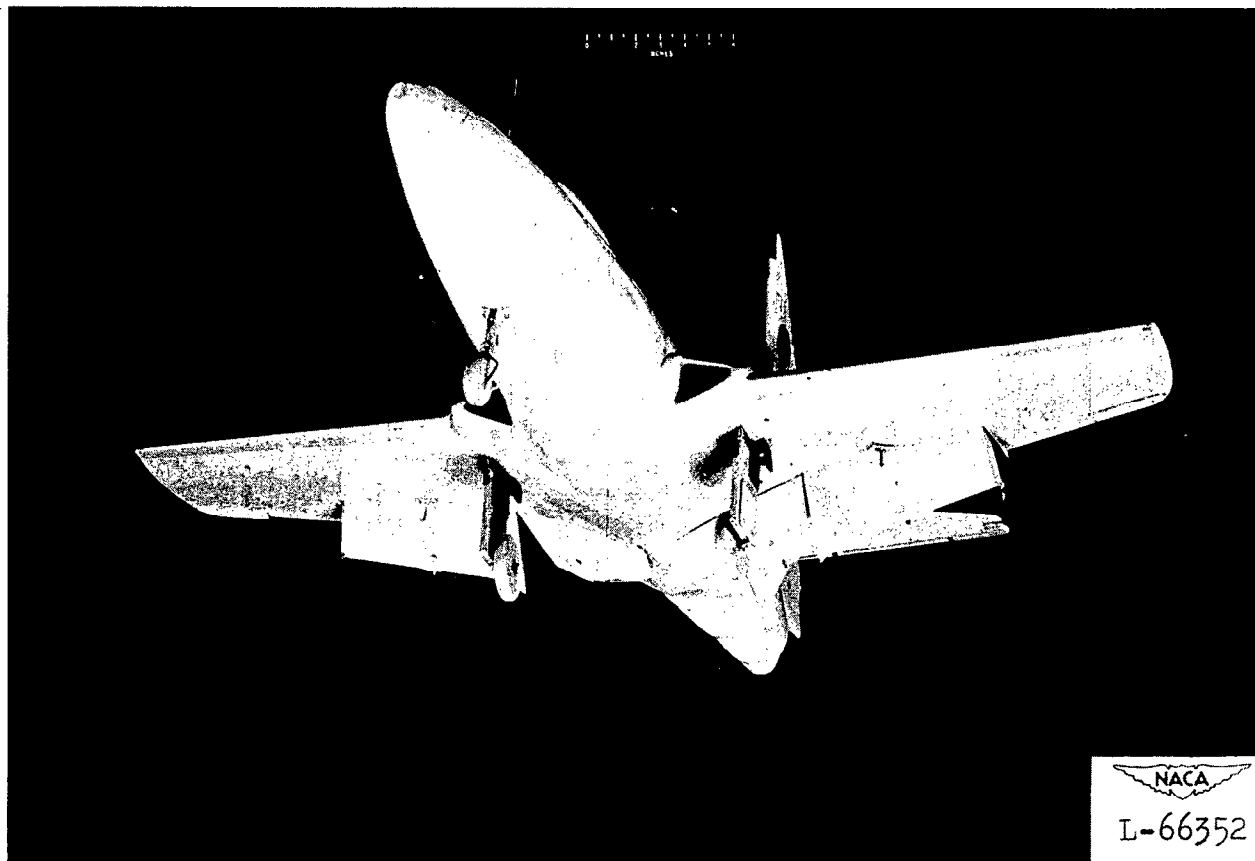


Figure 4.- Installation of the landing gear.

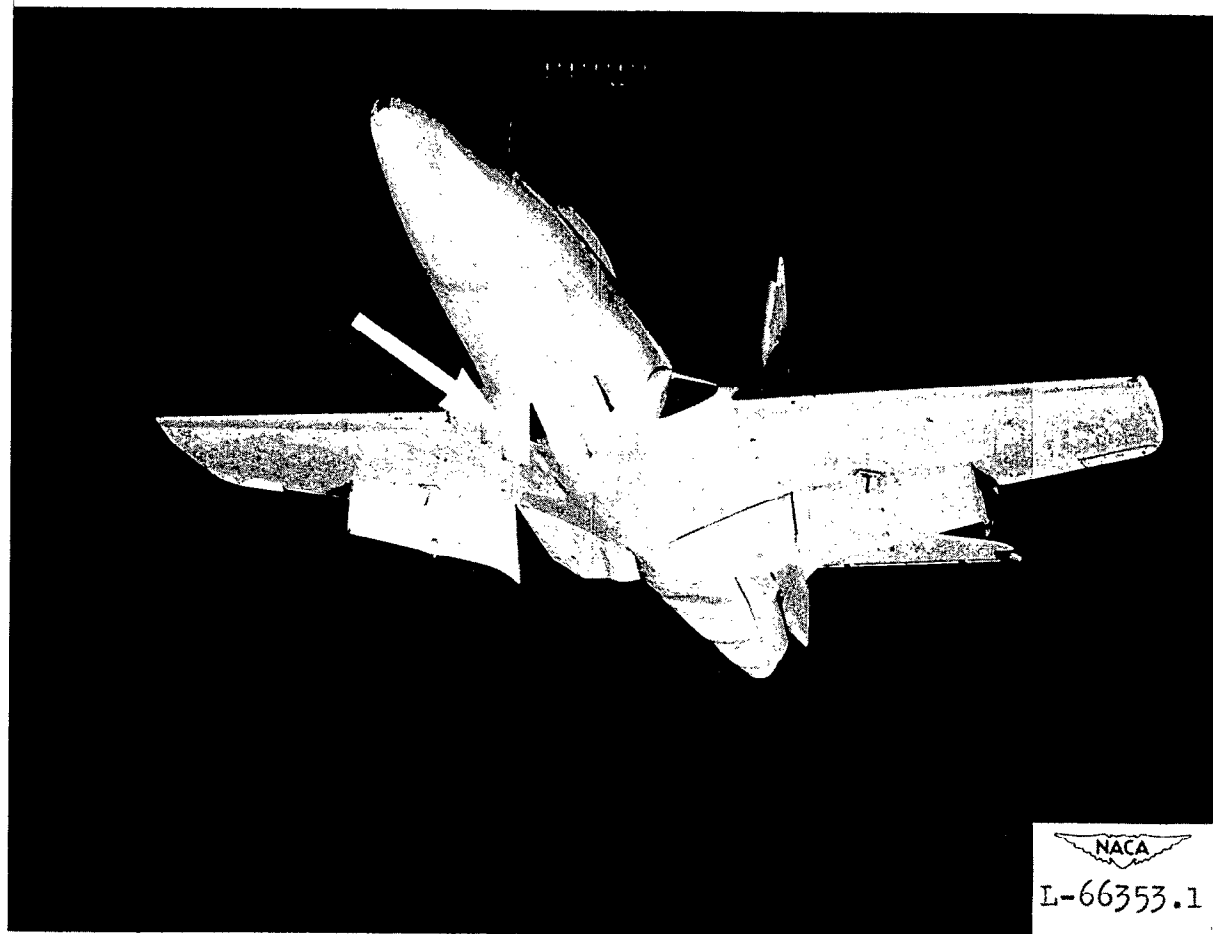


Figure 5.- Speed brake opened 30°.

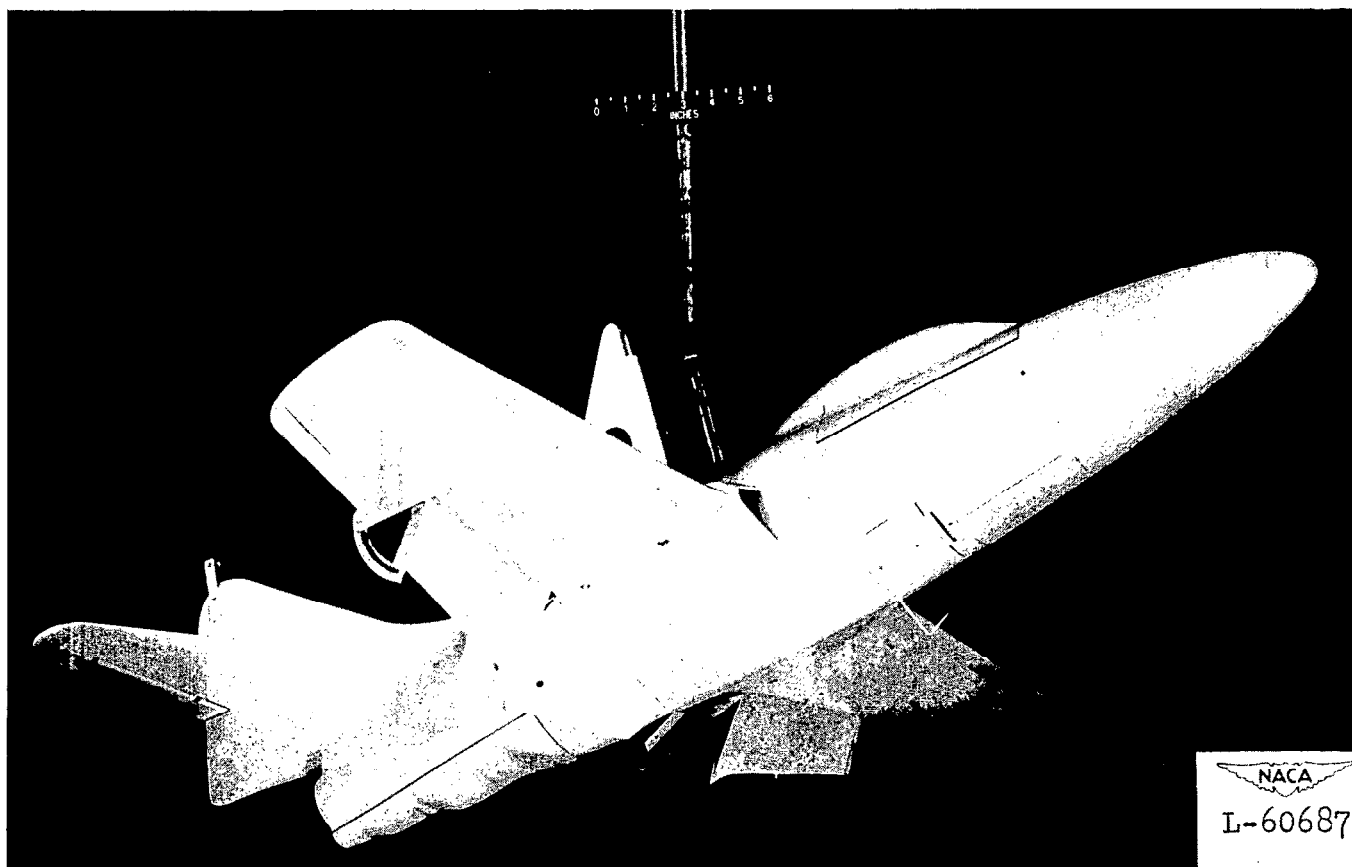


Figure 6.- Installation of the crumpled bottom.

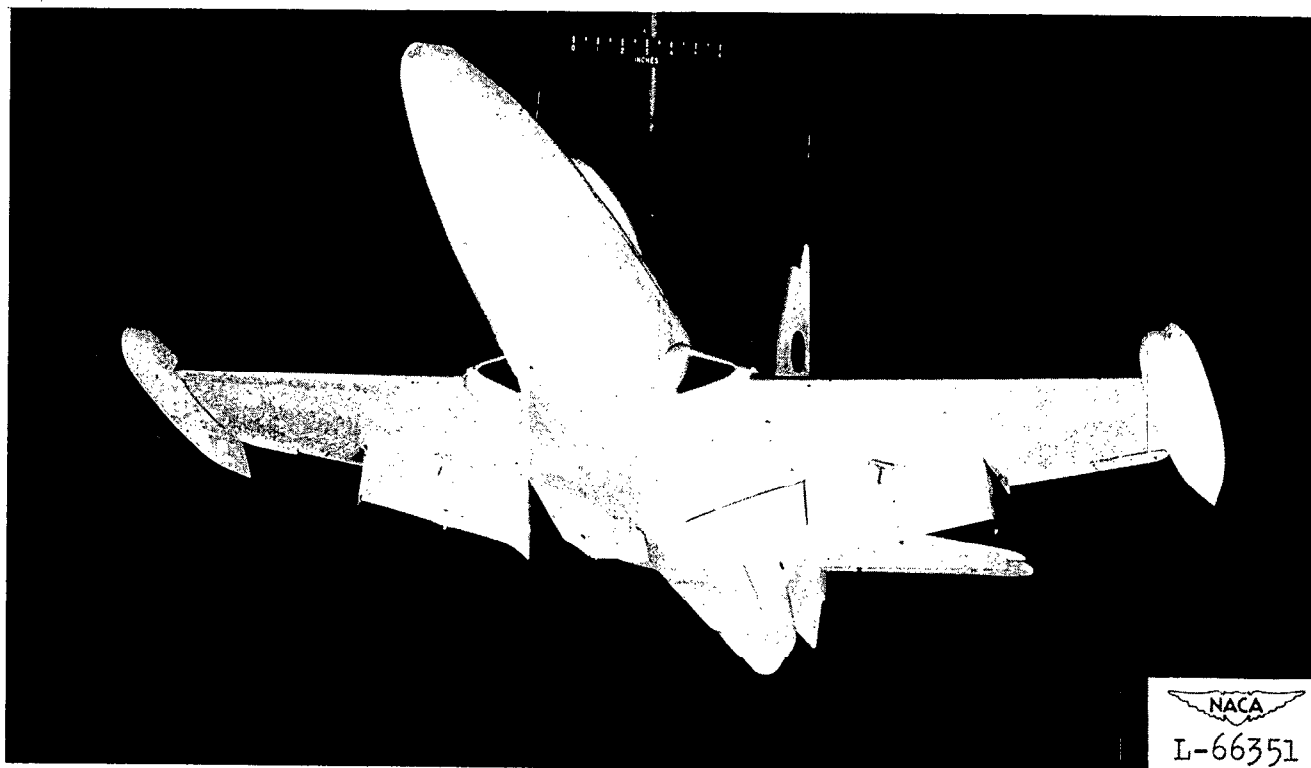
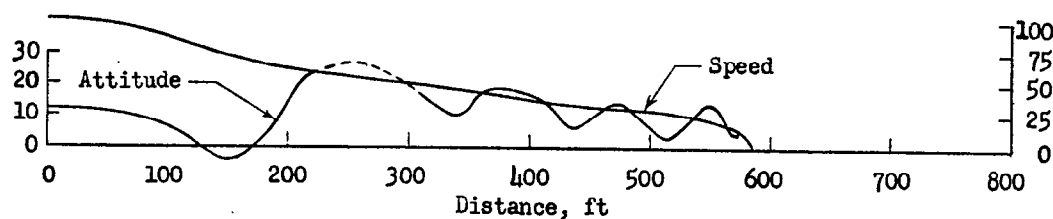
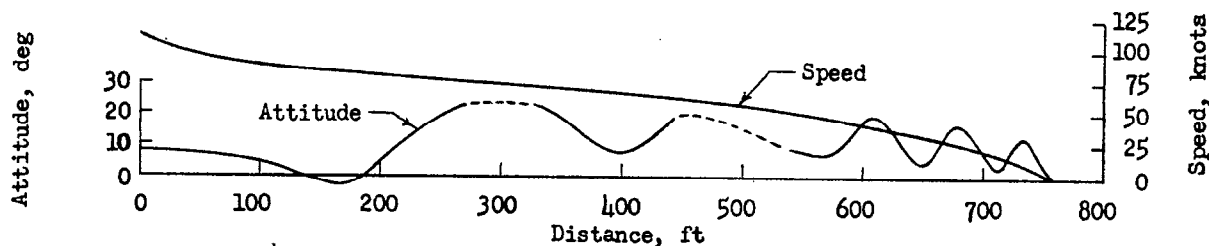


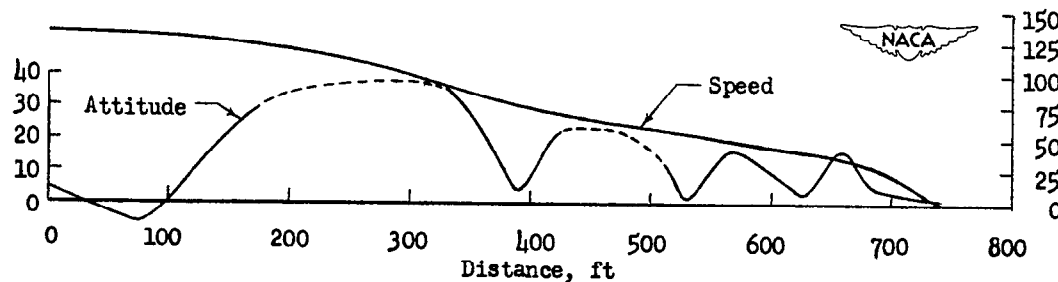
Figure 7.- Installation of the wing-tip fuel tanks.



(a) Landing attitude, 12° ; landing speed, 101.8 knots.

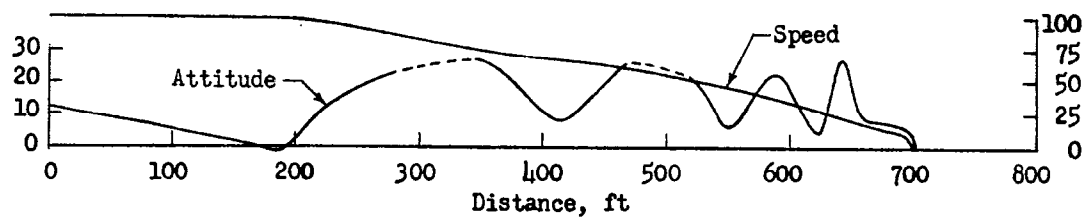


(b) Landing attitude, 8° ; landing speed, 114.2 knots.

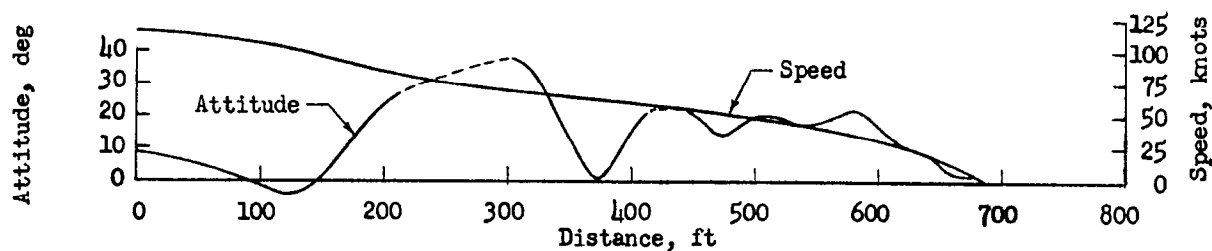


(c) Landing attitude, 4° ; landing speed, 133.0 knots.

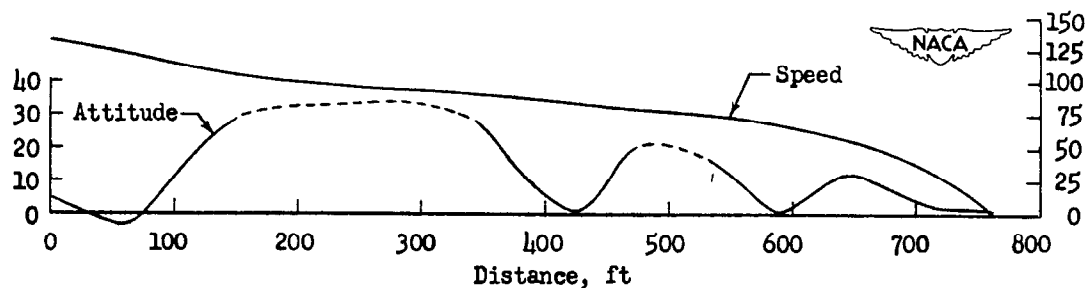
Figure 8.- Attitude and speed plotted against distance after contact for ditching tests of the undamaged model. Dashed part of attitude curve indicates model was clear of water. (All values are full scale.)



(a) Landing attitude, 12° ; landing speed, 101.8 knots.

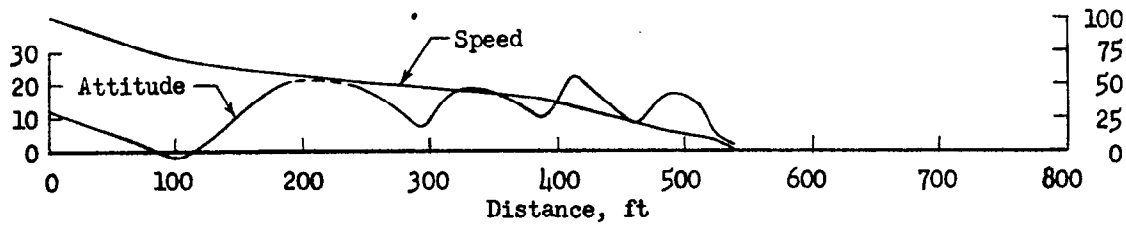


(b) Landing attitude, 8° ; landing speed, 114.2 knots.



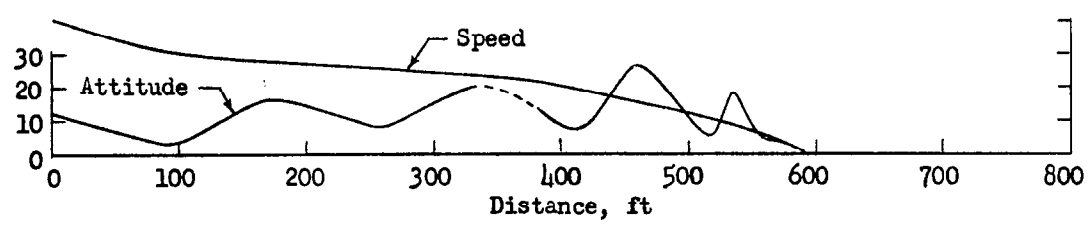
(c) Landing attitude, 4° ; landing speed, 133.0 knots.

Figure 9.- Attitude and speed plotted against distance after contact for ditching tests of the model with the simulated crumpled bottom installed. Dashed part of attitude curve indicates model was clear of water. (All values are full scale.)



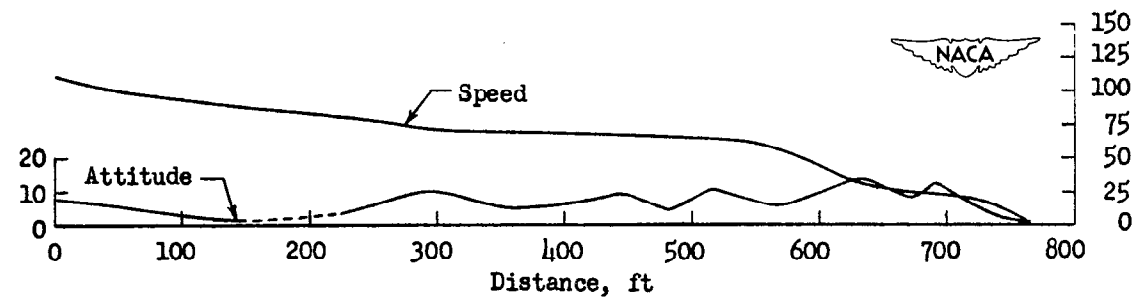
(d) Nose-wheel door removed; landing attitude, 12° ;
landing speed, 101.8 knots.

Attitude, deg



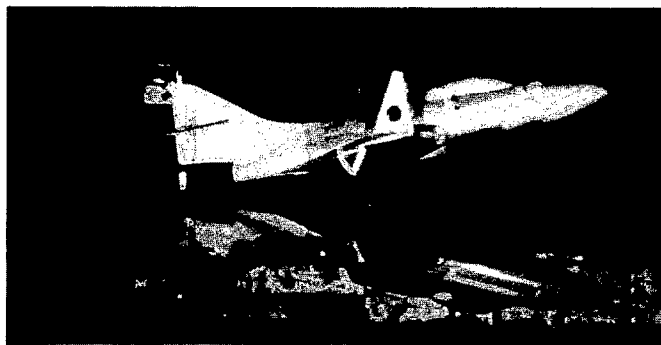
(e) Dive brake open 30° ; landing attitude, 12° ;
landing speed, 101.8 knots.

Speed, knots

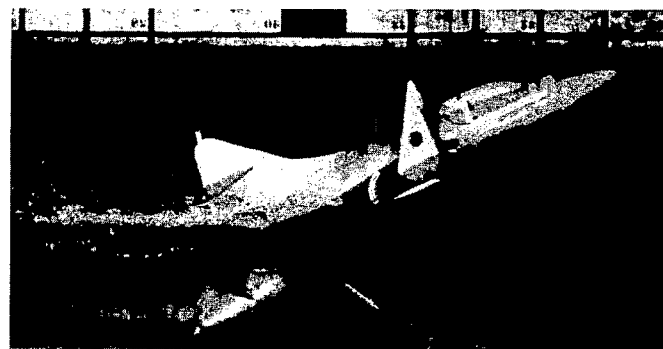


(f) Dive brake open 30° ; landing attitude, 8° ;
landing speed, 114.2 knots.

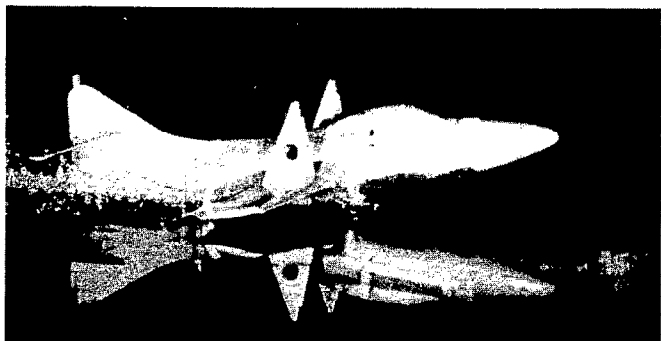
Figure 9.- Concluded.



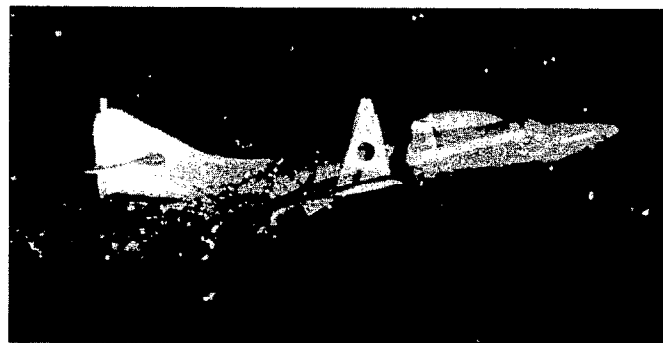
Near contact



220 feet



390 feet



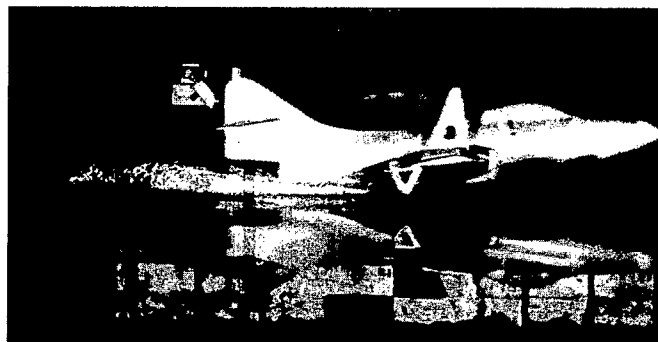
580 feet

(a) Landing attitude, 12° ; landing speed, 101.8 knots.

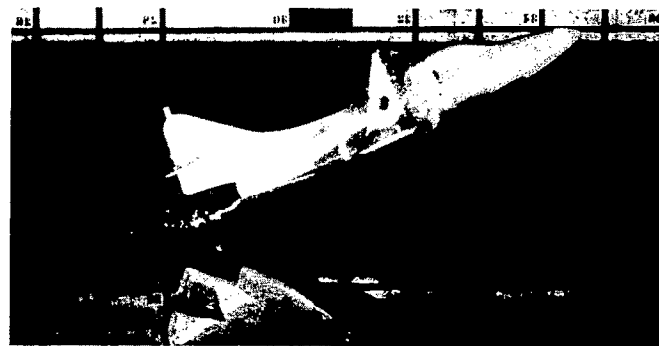
Figure 10.- Sequence photographs of model ditchings with the simulated crumpled bottom installed. Distance after contact is indicated. (All values are full scale.)



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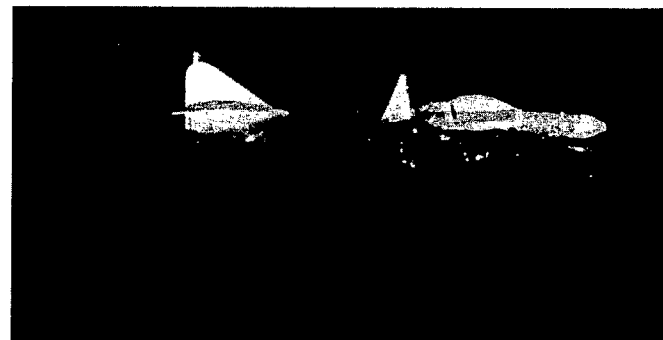
Near contact



210 feet



370 feet



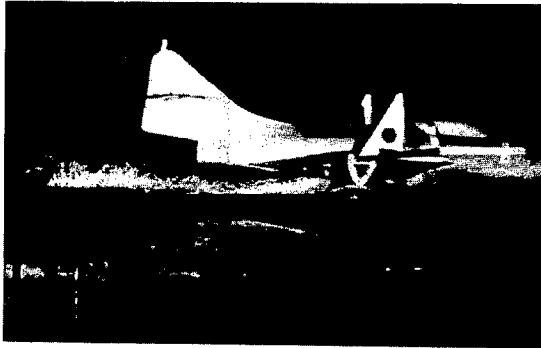
615 feet

(b) Landing attitude, 8° ; landing speed, 114.2 knots.

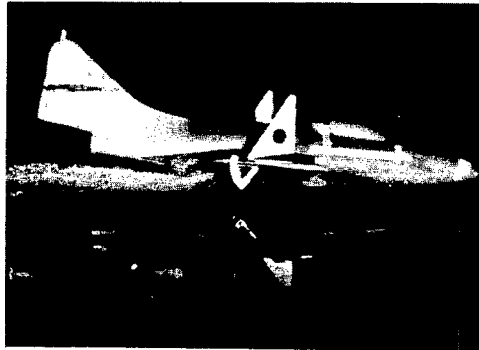
Figure 10.- Continued.



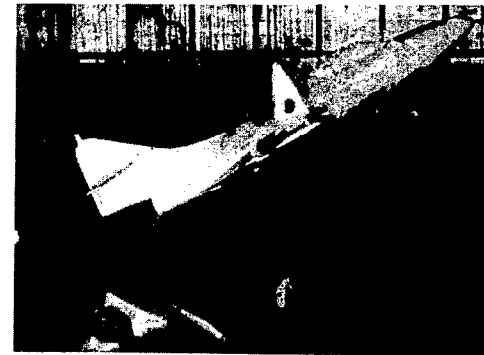
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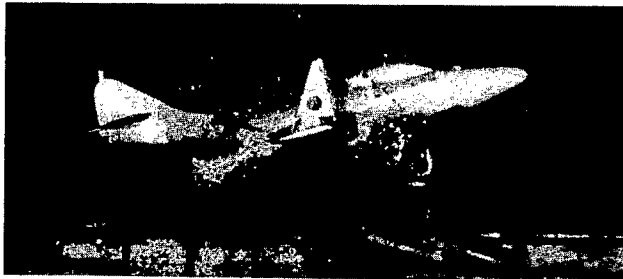
Near contact



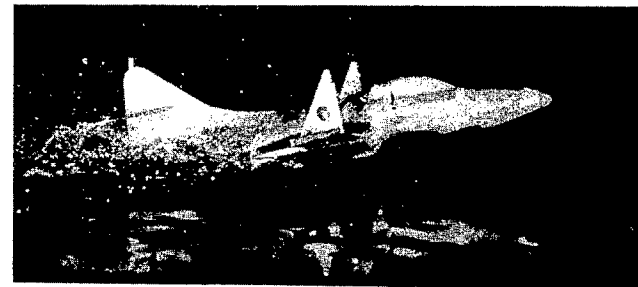
60 feet



225 feet



365 feet



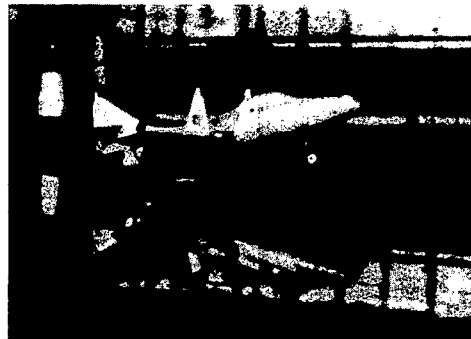
590 feet

(c) Landing attitude, 4° ; landing speed, 133.0 knots.

Figure 10.- Concluded.



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Near contact



46 feet



75 feet



92 feet



92 feet

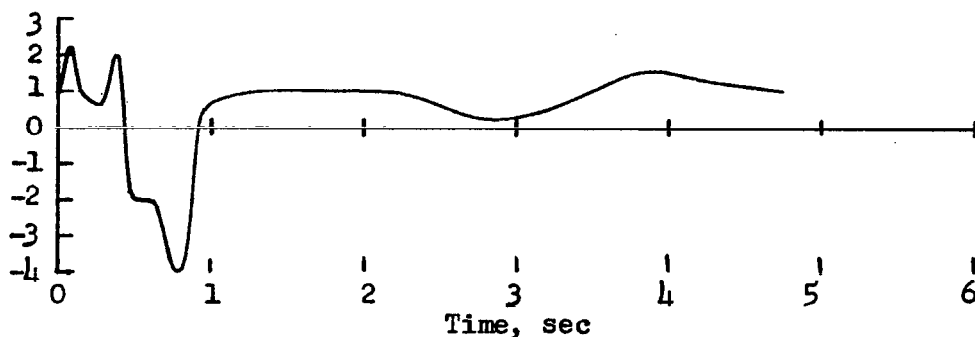


92 feet

Figure 11.- Sequence photographs of model ditchings with the landing gear down fastened at scale strength. Landing attitude, 14° ; landing speed, 82 knots. Distance after contact is indicated. (All values are full scale.)

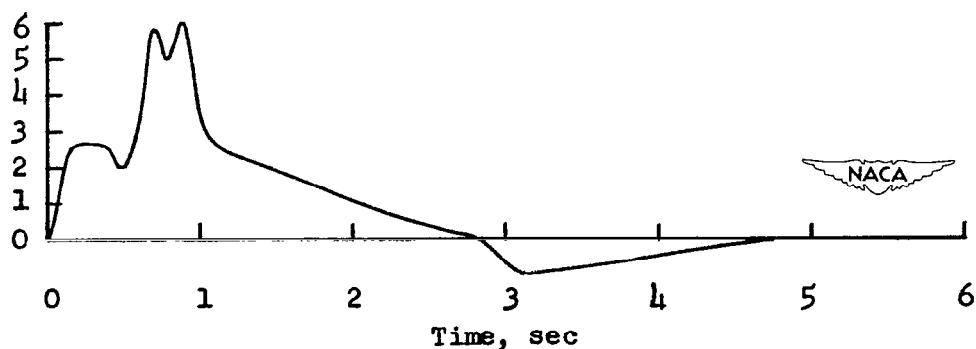


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(a) Vertical accelerations.

Acceleration, g



(b) Longitudinal decelerations.

Figure 12.- Typical time histories of vertical and longitudinal accelerations for ditching tests of the model with the landing gear down fastened at scale strength. Landing attitude, 14° ; landing speed, 82 knots. (All values are full scale.)

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